Income Intervention Quick Scan: Climate Change Adaptation

Farmer Income Lab Intervention Quick Scan

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Abstract UK This quick scan, commissioned by the Farmer Income Lab, is part of a wider research effort looking at, "What are the most effective actions that lead buyers can take to enable smallholder farmers in global supply chains to meaningfully increase their incomes?". The quick scan provides an overview of the publicly available evidence on the impact of climate change adaptation interventions have had on raising farmer income. Such subsidies have had little positive effect on farmer income, are not notably beneficial for women nor is this effect long-term. They have been applied at large scale. This quick scan is part of a series of 16, contributing to a synthesis report "What Works to Raise Farmer's Income: a Landscape Review".

Keywords: farmers' income, intervention, agriculture, smallholders, climate change adaptation, climate-smart agriculture, productivity

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Contents

List of abbreviations and acronyms

CCA-RAI	Climate Change Adaptation in Rural Areas of India
CCBAP	Cambodia Community Based Adaptation Programme
CSA-RA	Climate Smart Agriculture Rapid Appraisal
GIZ	Gesellschaft fur Internationale Zusammenarbeit
GHG	Greenhouse Gas
UNDP/GEF	United Nations Development Programme/Global Environmental Finance
WCDI	Wageningen Centre for Development Innovation, Wageningen University & Research
WUR	Wageningen University & Research

1 Introduction

1.1 Definition

Climate change adaptation interventions are defined here as: financial and in-kind support for farmers in the adaption of climate-smart agriculture practices and inputs (e.g. provision of climate-resilient seeds).

NOTE: This review focusses on two out of three objectives of climate-smart agriculture which link directly to farming income and livelihoods, namely i) adapt and build resilience against climate change, and ii) sustainably increase agricultural productivity. The third objective to mitigation GHG emissions is not assessed here. These two objectives are called climate change adaptation intervention strategies throughout the rest of this document.

1.2 Theory of change

Climate change will affect crop yields and consequently farmers' income (Reidsma et al., 2009). Projected impacts on production vary across crops and regions. In general, climate change without adaptation will negatively impact production levels in most developing countries - although beneficial impact can occur on regional level (Porter et al. 2014) and for specific crops (e.g. coffee). Climate change will particularly increase the inter-annual variability of crop yield and thereby impact income and food insecurity for farming households in vulnerable regions. (See Annex 1 for an example of climate change impact on rice production and adaptation actions from Nepalese rice farmers.)

Climate change adaptation aims to adapt the farming system in order to build resilience against climate change. The increased farming system's resilience should mitigate the negative impact of climate change on production levels and enhance production stability around levels similar to scenarios without climate change. This enhanced production stability may enhance farmer income stability under climate change (as compared to not adapting under climate change). Besides, the aim of climate adaptation is to increase agricultural productivity, what may increase farm revenues and may contribute to increased farmer income.

1.3 Geography

Climate change affects all countries and therefore climate adaptation interventions have been implemented all over the world. However, climate change is projected to have highest negative impact on agricultural systems in low-latitude regions (or, 'the global south') and especially in regions with extreme daytime temperatures around 30°C (Porter et al., 2014). Consequently, climate adaptation intervention programs have focused particularly on dry/hot area in the global south (e.g. sub-Saharan Africa, Sahel) and on other regions already vulnerable to food insecurity and poverty (e.g. South and South-east Asia). The case studies highlighted in this review were development projects in India and Ethiopia. The meta-studies covered all continents, and one modelling exercise used farm data from Zimbabwe.

1.4 Role of actors

Governmental institutions, donors and NGOs are identified in the reviewed literature as primary actors implementing climate adaptation interventions at farmer communities level. Governmental institutions seem to have had most direct interest in taking action with climate adaptation interventions, in order to support their vulnerable communities and to enhance national food security. Governments often seek partnerships with donor organizations for financial support and collaboration with NGOs for the implementation of programs. Most projects reviewed were implemented once per farming community and lasted for a couple of years. Some successful projects were identified for upscaling to other communities.

Other actors involved in the reviewed programs, were the targeted farming communities themselves. Farming communities were mostly engaged during the project implementation phase, by participating in trainings and self-help groups. Some projects also engaged communities during the project planning phase in order to tailor project design to address location specific challenges and opportunities, as well as to build community interest, commitment, ownership, and therewith enhance projects sustainability. Community engagement and empowerment has shown much potential for effective implementation of climate adaptation interventions. There was no evidence from the reviewed literature whether this approach enhanced long-term/sustainable adaptation, as none of the projects reported impacts beyond the project finalization. In theory, community empowerment with long-term access to required climate adaptation resources should allow for sustainable impacts, but this just remains a hypothesis here due to lack of direct evidence.

The reviewed literature showed no cases of private sector actors involved in climate adaptation intervention programs. It is evident that the private sector could play a strong role in supporting farming communities engaged in their direct value chain in the adaptation against climate change. This poses both opportunities for the farming communities in terms of income security, as well as for the private sector actors in terms of securing commodity supplies (which could be under thread when not adapting to climate change). The role of the private sector could be in initiating intervention programs and providing required resources and infrastructures to implement the adaptation practices (e.g. access to improved agronomic techniques such as drought-tolerant seeds and irrigation supplies, access to early warning climate information, training on best agricultural practices and the use of early warning systems, access to finance/credit, etc.).

2 Summary and justification of assessment

Strength of outcome		
Assessment criterion	**WUR score**	**Rationale for score**
<u>Scale:</u> Size of the population intervention could impact and potential to scale to other contexts (i.e., geographies, value chains)	HIGH	**>5,000 beneficiaries reached:** • Reported amount of beneficiary farmers ranged from 5,590 to 22,239 across all interventions reviewed (Harris & Orr, 2014; Porter et al., 2014; CCA-RAI, 2014; UNDP/GEF, 2016)
<u>Impact:</u> degree of increase in incomes	HIGH (income) MEDIUM (yield and productivity)	**>50% <u>income</u> increase:** • 3 out of the total 32 documents reviewed reported impact on income; all 3 reported an average positive impact on income. • Most extensive scientific review (Harris & Orr, 2014) reported average income increase of **200%** (N= 64), with large impact variability across cases from negative to negligible to positive. **10-50% <u>yield or productivity</u> increase:** • 4 out of all documents reviewed reported impact on yields; all 4 reported a positive yield impact. • The most extensive scientific review (Porter et al., 2014) reported average yield increase 15-18% (N= 263) with variability across interventions. • 1 out of all documents reviewed reported impact on agricultural productivity; which reported a positive productivity impact. • Development project evaluation (UNDP/GEF, 2016) reported average agricultural productivity growth of 12.5% - 100% (N= 2) with variability across interventions.
<u>Sustainability:</u> financial ability of farmer income increase to endure independent of ongoing external support	LOW	**Evidence of impact 0-2 years after external support ends:** • No evidence of impact beyond project termination across reviewed literature
<u>Gender:</u> Potential of intervention to positively impact women	LOW	**<25% of all interventions studied have at least a 50% female participation rate or refer to comparable measured gender specific income changes:** • None of the reviewed literature reported >50% female participation rate. • 1 project reported 45% female participation rate (CCA-RAI, 2014) • All reviewed literature reported farmer income only in general and lacked disaggregated income data for males and females.

Strength of evidence		
Assessment criterion	**WUR score**	**Rationale for score**
Breadth: amount of rigorous literature that exists on the impact of the intervention, as defined by the minimum quality of evidence for this paper	HIGH	**Conclusions drawn from at least 20 studies, either indirectly through meta-studies and/or direct individual studies**: • Short list of reviewed literature included 5 key studies, covering in total 335 intervention programs and 1 modelling exercise (Porter et al., 2014; Harris and Orr., 2014; Descheemaeker et al,. 2018; CCA-RAI, 2014; UNDP/GEF, 2016) • Still this is only the top the iceberg concerning available literature and therefore conclusions should be interpreted carefully.
Consistency: Degree to which the studies reviewed are in agreement on the direction of impact (i.e., positive or negative)	LOW (income) MEDIUM (yield and productivity)	**<25% of all studies reviewed include the income impact range identified**: • The average income increase of 200% is based on only 1 study, covering 64 intervention programs (19% of the total 335 intervention programs included in the overall assessment). **25-75% of all studies reviewed include the yield and productivity impact range identified:** • The average yield increase of 15-18% is based on 1 study, covering 263 intervention programs (70% of the total 335 intervention programs included in overall assessment). • The average productivity increase of 23-100% is based on 2 intervention programs (<1%) • Consistency across literature for positive impacts on income, yields or productivity. • Large variability across intervention programs for the extent of impact –likely due to variation in adaptation strategy, farming system, and/or region. • Negative or negligible impacts were never reported by development project evaluations, which might be due to reporting bias.

3 Methodology

Literature was searched in May 2018 across key databases: WUR Library, Google Scholar, and some database of development organizations. The GIZ (2015) Impact evaluation guidebook for climate change adaptation projects was key resource for climate change adaptation-related projects evaluations.

When searching in databases, the following key search words were used: climate change, adaptation, climate smart agriculture, impact, income, yield, productivity, smallholder farmers, meta-analysis, review, impact assessment, project evaluation.

A total of 19 scientific papers and 13 development project evaluations were reviewed (see Section 8: References). From this reviewed literature, the following documents have been identified to meet the standard for methodological rigor (i.e. relevant data reported), and were used for the analysis of climate change adaptation interventions:

Scientific literature

- **Porter et al. (2014)** Food security and food production systems. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Field et al. (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 485-533.
  N = 263 intervention programs; studies published 1994-2011
- **Harris and Orr (2014)** Is rainfed agriculture really a pathway from poverty? Agricultural Systems 123 (2014) 84-96
  N = 64 intervention programs; 22,239 farmers; year of surveys 1996-2008
- **Descheemaeker et al. (2018)** Effects of climate change and adaptation on the livestock components of mixed farming systems: a modelling study from semi-arid Zimbabwe. Agricultural Systems 159 (2018) 282-295
  N = 91 farms; modelling exercise

Development project evaluations

- **CCA-RAI (2014)** Climate Change Adaptation in Rural Areas of India (CCA-RAI) – Demonstration projects. Published September 2014.
  N= 7 intervention programs; 6,027 farming households / 20,099 individuals engaged
- **UNDP/GEF (2016)** Terminal evaluation of the UNDP/GEF Project: Promoting autonomous adaptation at the community level in Ethiopia
  N= 1 intervention program; 5,590 farmers engaged

Justification of referring to scientific modelling studies

A modelling exercise by Descheemaeker et al. (2018) was included among the selected literature, as models are valuable to explore the potential of adaptation strategies to future climate change scenarios. This is particularly valuable as climate change is often a challenge for the future, and thus the effect of climate change as well as the potential adaptation strategies cannot be measured directly. Models allow for early explorations of future climate scenarios, potential impacts on farming systems, and potential strategies to mitigate negative impacts of climate change on farmers' income. It should be noted that findings from such models should be interpreted as the potential impacts of the improved agronomic techniques exclusively, so without considering other confounding factors which might influence the actual adaptation impacts such as socioeconomic circumstances and the specific intervention approach.

Data gaps
Development projects reviewed failed to reflect on the impact of climate adaptation intervention on long-term income increases and income stability. Especially income stability is at risk under climate change due to the increased year-to-year variability of weather patterns and consequently variability in agricultural production. Also, when income increases were observed under climate adaptation, income variation across household within communities was never reported. With the lack of this kind of information, is remains unclear whether the highlighted projects actually enhanced sustainable and inclusive growth of farmers' income. Besides, it was not always clear whether reported income increases were net increases – so whether adaptation investments were included in the cost-benefit analysis. At last, development projects failed to reflect whether the increased incomes observed were directly due to the implemented climate adaptation practices and/or due to other confounding factors. Other unreported issues are: effectiveness of outreach (adoption), and effectiveness of participatory approaches to empower communities.

This review particularly focusses on shown effects of improved agronomic practices to increase yields, productivity and income. However, whether climate adaptation practices also lead to more resilient cropping systems is still a question. In many cases current, low-input (e.g. fertilizer) yields in rain-fed agriculture are more stable than yields that would be obtained under high-input conditions. So, yes, increasing input use (within safe margins!) improves productivity, but strictly speaking, this strategy is not necessarily climate-smart - also from the mitigation point of view.

While scientific reviews on the potential effect of different climate change scenarios on agricultural productivity are abundant, there is a lack of academic assessments on the potential impact of climate adaptation options. Studies which do focus on adaptation, mostly assess the impact on yields and/or productivity and do not assess impacts on indicators such as crop revenues or farm income.

The given timeframe to execute this literature review was insufficient to reach strong conclusions and essential nuances. There are dozens of other studies and projects out there from which lessons can be learned. Therefore, this paper should be interpreted as setting the scene for further research.

4 Impact

First of all, it is important to note that a cross-cutting cost-benefit analysis of agronomic adaptation strategies is not feasible, due to the location-, time-, and climate change-sensitive nature of adaptation decisions – which above that nature also interact with highly contextual driving factors (Porter et al. 2014; UNDP, 2015). Therefore, a local assessment of risks, needs and opportunities is always required to ensure effectiveness of intervention strategies. The highlighted studies below show examples of the potential impact of climate adaptation interventions on farm(er) income, yields or agricultural productivity.

4.1 Impact on farm(er) income

- Increased net farm income: 200% (N=64; scientific meta-analysis)
- Increased annual average farmer income: 23%-100% (N=7; development project evaluation)
- Increased net revenues from livestock products by 20% (N=1; scientific model)

Improved crop production technologies in rain-fed farming systems in SSA and India have shown to **increase median net farm returns** by **200%** (from $186/ha/season under current production, to $558/ha/season under improved production). These are results from a meta-analysis done by **Harris and Orr (2014)** on **64 case studies** (totalling 22,239 farming households) from India and sub-Saharan Africa which measured the impact of crop- and natural resource management interventions for rain-fed crop production systems on net farm returns. Rain-fed farming systems are particularly interesting for climate adaptation interventions, as they are most vulnerable for the increased rainfall variability due to climate change. All analysed case studies included different combinations of crops (mainly cereals and legumes) and intervention strategies. All interventions were improved agronomic technologies within the categories: Tillage, Rotation fallows and intercropping, Fertilizers and soil amendments, Pest and disease control, and Improved varieties. Overall, the improved technologies proved very effective to increase net farm returns. The median increase of net returns when moving from current to improved crop production technology was $372/ha/season, or 200% (from $186/ha/season to $558/ha/season respectively; all $ values are in 2005 PPP). However, even when correcting for outliers, net farm returns varied largely across case studies from negative values to around $900/ha/season under current technology, and from $120/ha/season to around $1700/ha/season under improved technology.

Some important notes for interpretation of these results:

- The values for net returns were mostly derived from small-plot studies and are likely to be overestimates when technologies are implemented by farmers on larger areas.
- The net incomes were fairly low (*de factor* limit of around $1700/ha/season) - mostly due to small farm sizes. As the actual impacts on farmers' livelihoods are often so small, they may not present a convincing incentive for farmers to make investments/change farming practices. Hence, field or farm-level adaptation of current systems may not be enough and more transformative changes in the wider institutional context are needed.

Increased annual average farmer incomes between **23% and 100%** were observed under **7** different climate change adaptation intervention projects among rural farming communities in India (**CCA RAI, 2014**). Project activities varied largely, from for example improving pasture management and livestock rearing, livelihoods diversification through integrated production systems, introducing salt-tolerant species, and rainwater harvesting. The annual average income increases observed (= income difference between start and end of 2-year project) varied across interventions: 40% under a soil water conservation program, 70% using integrated pasture management, 70%-100% using integrated production systems, and 23% by the introduction of salt-tolerant paddy (rice). A total of

20,099 individuals (6,027 households) were reached with the adaptation measures. Income variability across household was not reported.

Improved crop-livestock management showed potential to mitigate the negative effect on income from climate change. A modelling exercise with 91 Zimbabwean mixed crop-livestock farms showed potential to **increase net revenues from livestock products** by **20%** under crop diversification plus improved soil management - as compared to revenues under the current system with climate change **(Descheemaeker et al., 2018)**. The model calculated that without climate adaptation, the Zimbabwean farms would face a negative effect on livestock production and farm revenue under future climate scenarios. This was mainly due to the increased year-to-year variation in livestock productivity, causing relative changes in livestock net revenue varying from 6% increase to 43% decrease compared to the current climate scenario. Climate change adaptation strategies showed potential to decrease year-to-year variation in revenues up to 13% as compared to the current system, which could increase net revenues from livestock products up to 20%. Whereas nearly all farms faced declining net revenues under the future climate scenarios without adaptation, crop diversification reduced this proportion to 60-76% of the farm population (under different climate change scenarios: RCP4.5 and RCP8.5 respectively).

Prato et al. (2010) showed that agronomic adaptation can mitigate the negative effect of climate change on farm income (adapting provides higher net farm income than not adapting), but cannot always compensate all income losses caused by climate change. This means that adaptation to future climate change is not always sufficient to offset the adverse impacts on net farm income of such changes. Therefore, climate adaptation interventions ideally include practices to both increase the resilience and yields and/or productivity of agricultural production systems.

4.2 Impact on yields

- Increased yields: 15-18% (N= 263; scientific meta-analysis)

An extensive review on the potential impact of climate change adaptation in food production systems was done by Porter et al. (2014) for the fifth IPCC report. The meta-analysis included 32 scientific studies (published from 1994-2011), which in total referred to yield impacts of 263 climate adaptation interventions. Results showed that agronomic adaptation strategies on average improve yields by 15-18% compared to current yields. However, the effectiveness of adaptation is highly variable ranging from potential negative to negligible to positive effects, depending on the adaptation strategy, crop, and region. The most effective crop management adaptation observed is cultivar adjustment (23% yield benefit), followed by combined adjustment of planting date and cultivar (17% yield benefit), irrigation optimization (3.2%), planting date adjustment (3%), and fertilizer optimization (1%).

Some extra reviewed individual studies showed comparable or even higher yield impacts:

- Climate adaptation practices among Nepalese rice farmers increased rice yields with 30%, as compared to not adapting (Khanal et al., 2018).
- Maize yields in Uganda are projected to drop around 4% with future climate change scenarios. Improved soil fertility management can mitigate this effect and even increase maize yields by over 50% (Kikoyo & Nobert, 2014).
- As shown with a modelling exercise, CO2-fertilization on coffee has potential to mitigate the negative effect of temperature increase and drought stress to coffee yields up to 13-21% (variation depending on site conditions) and can increase coffee yields at higher altitudes (Rahn et al. 2018).

4.3 Impact on agronomic productivity

- Agricultural productivity growth: 12.5% - 100% (N= 2; development project evaluations)

The project ‘Promoting autonomous adaptation at the community level in Ethiopia’ (UNDP/GEF, 2016) was a governmental development program in 8 rural Ethiopian rain-fed subsistence farming communities during the cropping seasons of 2015 and 2016. The project achieved agricultural productivity growth across communities through the combination of different climate change adaptation interventions:

- Provision of user-friendly early warning climate information (in local language) and training to effectively use that information for planning timing of operations (sowing and harvesting) was provided to 1,269 farmers (42% woman). Consequently, farmers were better resistant against changing rainfall frequency and water scarcity and achieved estimated agricultural productivity growth of 100% on 1,800 ha of land. Variability of productivity growth across farmers was not reported.
- Improved practices were trained to 5,043 farmers (47% women) in order to combat different water scarcity scenarios. The project supported to construction of small scale irrigation powered by solar energy that included rain water harvesting structures, as well as community ponds, and structures to divert surface water streams and ground water to reservoirs and overhead tanks. Besides, soil-moisture conservation practices were trained to 3,885 farmers (40% woman). Trained farmers used these new adaptive techniques on 1,200 ha of farm land with maize, teff, vegetables and fruits, and were able to increase their agricultural productivity by 12.5%.

--> In total, this project benefited 5,590 farmers (45% woman) in 8 communities to improve their livelihoods. It was reported that farmers were able to increase productivity of vegetables, medical plants and animal products. This increased their food self-sufficiency, and allowed for selling crops on the market. Therewith the community generate income of about 20,274,392 Birr in total (= 3627 Birr, or 132 USD per farmer on average). Unfortunately, it was not stated in the project evaluation report whether income increases varied across households within the community, whether the interventions specifically impacted woman, and to what extent this total income was directly due to the climate adaptation interventions. Therefore, we cannot extrapolate conclusions from this project further than the observed agricultural productivity increases stated above.

4.4 Upscaling of interventions

There is a high potential for upscaling within a specific community. Reviewed projects included up to 5,590 farmers per intervention (CCA-RAI, 2014; UNDP/GEF, 2016). Further upscaling is likely feasible. The potential for upscaling within a specific region is high, provided there are homogeneous climate (change) patterns and farming systems (UNDP/GEF, 2016). The counter is also true: there is limited potential for scaling to other contexts. Especially scaling to different geographies is challenging as climate change is very location specific and thus adaptation decisions are highly contextualized (Porter et al., 2014).

4.5 Applicability of impact

Impact of climate adaptation interventions on woman is not explicitly reported in any of the reviewed literature.

The literature was not explicitly reviewed for interventions implemented in cocoa, rice, or mint value chains – and therefore no conclusions are stated about these crops specifically. Moreover, the reviewed literature included multiple different crop and/or livestock sector, implying that much care should be taken with generalizations of results.

Based on the reviewed literature, we can conclude that the farmer segments (as defined by Dalberg) most impacted by climate adaptation interventions are: *subsistence farmers* and *pre-commercials farmers*. It should be noted that all other farmer segments (i.e. *ultra-poor*, *commercial farmers* and *agribusinesses*) also face risks under future climate change scenarios and have large potential to gain positive impact from climate adaptation interventions.

4.6 Enhancing the intervention

The most outstanding intervention package observed from the reviewed literature was a development project in implemented by the government of Ethiopia (collaboration between national, regional, and local offices) in 8 rural Ethiopian rain-fed subsistence farming communities (UNDP/GEF, 2016). The intervention bundled the introduction of a weather index based crop insurance mechanism, with provision of user-friendly early warning climate information, and trainings on i) the effective use of climate information of planning timing of operations, ii) improved water management, and iii) soil-moisture conservation practices. The project piloted methods of adaptation to improve coping capacity of both community and governing institutions, to secure livelihoods and the ecosystem which were endangered due to climate variability. The project achieved improved societal awareness and preparedness for climate risks, improved household income allowing for livelihoods diversification, and enhanced ecosystem functioning and services through natural resource management. The project benefited 5,590 farmers (45% woman) to improve their livelihoods and demonstrated capability for up-scaling. Consequently the Ethiopian government decided to introduce the project in 150 more communities.

5 Key success factors

Access to credit and/or insurance mechanisms is shown to enhance climate adaptation of smallholder farming households (Shikuku et al., 2017; UNDP/GEF, 2016). The UNDP/GEF project showed that the inclusion of Weather Index Based Crop Insurance mechanisms in the intervention package (also including access to early warning climate information access and improved soil and water management training) provided 76% of the farmers with insurance pay outs during a period of harvest loss due to extreme rainfall variability. This insurance mechanism provided farmers income security and allowed them to continue investments in improved agricultural practices.

Good understanding of climate resilience needs, specific to the location and/or agricultural system allows for relevant and effective climate adaptation strategies and promotes the intervention's success. Information is preferably based on a combination of both scientific background, climate scenarios and indigenous knowledge gathered through focal discussion groups (CCBA, 2013). Climate Smart Agriculture Rapid Appraisal (CSA-RA) demonstrated an effective methodology for identifying and prioritizing locally appropriate climate interventions (Mwongera et al., 2017). This rapid yet comprehensive tool relies on a multi-stakeholder participatory approach and a mixture of gender, climate, household and economic analysis to assess context specific climate adaptation priorities.

Cooperation with the communities and partner organizations with local experience in both the planning and implementation phase promotes the success of intervention. Such collaboration might simultaneously enhance the coping capacity of communities and strengthen institutional capacity of partner organizations. During the planning phase, execution of a local vulnerability and opportunity assessment is strongly recommended to ensure effective and realistic adaptation strategies. During the implementation phase, regular exchange with the implementing organization (e.g. through participatory workshops, site visits, and trainings), and active community participation throughout the project (e.g. through self-help groups) are essential to build community interest, commitment, ownership, and projects sustainability (CCA-RAI, 2014; UNDP/GEF, 2014). Building on agricultural system model development, integrated impact assessments and scenario analyses can inform the co-design and implementation of adaptation and mitigation strategies (Descheemaeker et al., 2016).

Providing long-term access to knowledge and other resources is important to ensure sustainable success of interventions. Long-term adoption can be enhanced by providing access to required knowledge and resources to continue practicing the adaptation techniques after termination of the project. The UNDP/GEF project in Ethiopia provided farmers access to user-friendly early warning climate (in local language) and trained 1,269 farmers (42% woman) to effectively use information for planning timing of operations (sowing and harvesting). Consequently, farmers were better resistant against changing rainfall frequency and water scarcity and achieved estimated agricultural productivity growth of 100%, at project termination as compared to the project start. Unfortunately this project did not report whether the information remained available after project termination and whether successful adoption continued.

The combined introduction of supplementing intervention strategies which enhance access to knowledge, resources, and finances is an important factor for success. For example, the combined introduction of crop insurance mechanism, provision of early warning climate information, and trainings on improved soil and water management, empowered rural Ethiopian farming communities with required climate adaptation capacity to secure and even increase their income (UNDP/GEF, 2014). Also the combined implementation with post-harvest technology that allows good storage of products, is an effective climate smart practice (Milgroom & Giller, 2013). In that way, households can overcome crop failure and/or reduced production during drought and increase their resilience in terms of food or income security.

The use of complex technical and social solutions is an implementation factor which can constrain success, as these solutions often rely heavily on financial resources, materials and knowledge without ensuring (increased) effect. For realistic and practical implementation, it is recommended to base on experiences elsewhere. The use of technical and social interventions based on existing local knowledge and resources can ensure low implementation costs. For example, members of Farmer Water Use Groups in the CCPAP project (2012) together ensured that community water was divided over all land according the location- and time-specific demand (CCA-RAI, 2014).
Shifting environmental stress to adjacent areas can also constrain the success of the intervention, as is does not solve but merely shifts the problem. For example, harvesting surface water, groundwater or rainfall water may cause water stress in other regions where the water would have flown naturally (CCBAP, 2013).

Short-term interventions might be most successful when enhancing farming systems resilience through providing climate information (to inform timely planting and harvesting), promoting crop diversification, and encouraging adoption of adapted crop varieties. For long-term sustainable adaptation, increased investment in reducing hunger and encouraging groups formation are required to promote improved soil, water and land management which enhance climate resilience. These findings from Shikuku et al. (2017) were drawn from observations among 500 smallholder farming households across Ethiopia, Uganda and Tanzania. Results of this study showed that farmers strongly favored introduction of new crops, changes in crop varieties, and changes in planting times as climate adaptation strategies; while farmers disfavored changes in soil, land and water management practices. Adaptation was enhanced at households with farmer group membership, and adaptation was especially high at households with access to credit. Food insecure households showed negative correlation with adaptation, suggesting that hunger is a barrier to climate adaptation.

Rain-fed farms have a higher potential impact from climate adaption interventions as compared to irrigated farms. This is due to the fact that production levels at irrigation farms are (more) independent from rainfall patterns and therewith are already (partially) adapted to climate change. So interventions related to rainfall (variability) are likely most effective when targeted at rain-fed farmers (Harris and Orr, 2014).

Focus on households most vulnerable to climate-induced stress likely enhances the level of impact of interventions. Households most vulnerable to climate-induced stress are: large and/or female-headed households with little resources, little complementary sources of income and with poor access to extension services, early warning information, markets and credit (Opiyo et al., 2014). Key factors for success when working with these kind of households are the inclusion of a gender-sensitive working approach, plus the facilitation of essential extension services, resources and access to credit.

6 Barriers addressed

Food insecure households showed negative correlation with adaptation, suggesting that hunger is a barrier to climate adaptation (Shikuku et al., 2017).

Porter et al. (2014) report that common barriers to adaptation are:

- Lack of adaptive capacity of farmers
- Inadequate extension
- Institutional inertia
- Cultural acceptability
- Financial constraints including access to credit and insurance
- Inappropriate infrastructure
- Lack of functioning markets.
- Enhanced access to climate information can lead to increased inequities and widening gender gaps.

Therefore, inclusive and gender-sensitive approaches are recommendable.

7 Questions for further research

- Which climate adaptation interventions have shown to enhance sustainable and inclusive growth of farmers' income, by stimulating long-term income increases especially for the most vulnerable farmers such as female-headed and resource-poor households?
- What is the impact of climate change adaptation interventions on farming system resilience (focus on entire farming system instead of one crop), gender equity, and farmers' livelihoods?

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--> Includes overview of current CCA-related project evaluations (Table 5.1; pp. 49-52).

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Appendix 1

Nepalese rice farmers' perception on climate change, its impact on rice production and adaptation actions (adapted from: Khanal et al., 2008).

	Climate hazard	Farmer perceived effect on rice yield production	Adaptation actions acted by farmers
Parameter: temperature	- Increased temperature	- Increased evapotranspiration, thus require more irrigation - More infestation of insects and diseases - Introduction of new insects and diseases - Reduced grain quality - Yield reduction	- Grow short duration varieties' - Grow insect and pest resistant varieties. - Change planting location of varieties - Improve irrigation - Increasing number of weeding - Use more pesticides
Parameter: Precipitation	- Change in timing of rainfall including late start of monsoon - Decreased availability of surface and ground water - Long spell drought - Less frequent but heavy rainfall causing flood and landslides	-Poor germination - Water stress causing less tiller number - Delay panicle initiation - Reduce grain and panicle number - Delay in transplantation - Shortage of irrigation water - Loss of crop due to heavy rainfall/hailstorm - Destruction of water resources and irrigation canal - Degradation of soil quality - Yield reduction	- Soil conservation techniques - Reduce tillage - Seed priming - Change planting location of varieties - Change sowing/planting/harvesting date - Cultivation of direct seeded rice - Increase seed rate - Grow short duration varieties - Grow drought tolerant varieties - Improve/increase chemical fertilizer use - Improve/increase farm yard manure use - Construction of water ways during heavy rainfall - Grow flood tolerant varieties - Switch to non-rice crop

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